

Improving Large Cetacean Implantable Satellite Tag Designs to Maximize Tag Robustness and Minimize Health Effects to Individual Animals

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LONG-TERM GOALS

This project was designed to develop robust implantable satellite tags for large cetaceans considering observed tag design flaws observed during follow-up studies conducted with Gulf of Maine (GOM) humpback whales (*Megaptera novaeangliae*) (Robbins et al. 2013, Zerbini et al. 2013). In addition, potential trauma caused by muscle penetrating devices (Moore et al. 2013) will be evaluated through experiments on cetacean carcasses. These experiments along with existing information on tag vulnerabilities will inform development of new tag designs that are expected to minimize potential health effects to individual whales while maintaining or improving tag duration.

OBJECTIVES

The specific objectives of this project are as follows:

- 1) Design, build, and test robust blubber and/or muscle penetrating tags, which will (a) resolve structural limitations of existing designs (e.g. those found during the Gulf of Maine humpback follow-up study) and (b) minimize tissue trauma while extending retention time;

- 2) Evaluate structural integrity of designs created in Objective (1) during laboratory experiments and in cetacean carcasses;
- 3) Examine structural tissue damage in the blubber, sub-dermal sheath and muscle caused by penetrating dummy implantable tags in cetacean carcasses, including manipulation to simulate live motion;
- 4) Assess performance of the new tags in populations of large cetaceans where extensive follow-up studies can be performed (e.g. Gulf of Maine humpback whales and eastern Pacific gray whales, *Eschrichtius robustus*).

APPROACH

This project will evaluate the magnitude of tissue trauma caused by shearing when implantable tag devices penetrate the sub-dermal sheath at different parts of a cetacean body. This assessment will be conducted in carcasses and its results will, along with existing information on tag vulnerability, inform the development of new tags. Impact tests on new designs will be performed in the laboratory as well as in fresh carcasses to ensure new tags and retention devices are robust to the forces to which they are subject during and after deployment. Improved tags will be deployed in free ranging GOM humpback whales and in eastern Pacific gray whales in the spring/summer 2015 and 2016. Tag performance will be assessed during follow-up studies. These populations were chosen because they have been subject to intensive, fine temporal scale follow-up studies, and because implantable satellite tags have been previously deployed to some of their individuals. Therefore, existing information on tag performance and potential health effects will be compared with results of new tag deployments. Final tag designs will be made publicly available to the marine mammal community after the conclusion of the project.

This study has been carried out by scientists and engineers from eight organizations: Cascadia Research Collective (CRC), Woods Hole Oceanographic Institution (WHOI), the Alaska Sea Life Center (ASLC), the Australian Marine Mammal Centre (AMMC), the National Marine Mammal Laboratory (NMML), the Provincetown Center for Coastal Studies (PCCS), Texas A&M University (TAMUCC), and Wildlife Computers (WC).

WORK COMPLETED

1. ASSESSMENT OF TISSUE DAMAGE AND SHEARING AT THE MUSCLE/BLUBBER INTERFACE

Additional experiments to evaluate shearing at the muscle-blubber interface and consequential trauma caused by intramuscular implantable tags were conducted in the laboratory at WHOI. The extent of the mobility of the blubber over the muscle during the locomotory cycle were measured in common dolphin (*Delphinus delphis*) cadavers (considered a tractable laboratory model). With the cadaver on a table, using Dyneema line purchases between the dorsal fin and peduncle or flippers and peduncle respectively, to maintain full dorsal or ventral flexion, 17 gauge needles (1.5 mm diameter) were inserted on the midline anterior to the dorsal fin and dorso-laterally in two rows at sites equivalent to potential tag implant sites from anterior to posterior of the dorsal fin (Fig. 1). The needles were inserted in diads or triads, having one penetrating the blubber only and the other one/two through the blubber and at different depths (2 and 4 cm) into the muscle. The angle of penetration was measured for each needle using a protractor (Fig. 1), with the animal in the relaxed, dorsal flexed and ventral flexed positions. The change in angle for each needle was calculated between dorsal and ventral flexion. A pneumatic oscillator to mimic swimming movements was built to evaluate the muscular

trauma induced by cyclical flexion and extension of chilled dolphin cadavers after scaled dummy tags had been inserted at a series of stations in the dorsal aspect of the animal.

2. TAG DESIGN TESTING AND MODIFICATIONS

Implantable tags (e.g. Gales et al. 2009) used prior to this project showed design faults, which were only identified during follow-up studies on GOM humpback whales (Robbins et al. 2013, Zerbini et al. 2013). During the first year of this project, modifications to tag designs were made to improve tag robustness, including the integration of the anchoring system and the transmitter housing in order to eliminate the anchor-transmitter interface and a redesign of the posterior end of the transmitter. Details of these changes and the configuration of an improved implantable tag design were presented at the previous report (FY14). The fully integrated tag is illustrated in Fig. 2 and will be referred to here as Mold 303B.

Further changes to tag design were evaluated, in particular with regards to the shape of the tag tip and the retention devices. Laboratory testing of miniature and full size tags were conducted to better inform the design. These test included insertion (push-in) and extraction (pull out experiments) of miniature tags with a load cell (Fig. 3) on a small whale carcass to assess penetration and retention power of the existing and alternate anchor tips and retention devices. Results led to the development of a new tag, which included changes in shape of the anterior portion of the tag, a new tip, and new retention petals. The new tip was required because field observations previously indicated that the asymmetrical shape of the double blade tip from Mold 303B could result (depending on the angle of contact between the whale skin and the tag tip) in a change in the trajectory of the tag upon penetration, with consequential suboptimal anchoring of the tag. Laboratory and field observations showed that the retention devices on Mold 303B also showed potential for delayed engagement and/or breakage. Prototype housings of this new tag design, referred to here as Mold 303E (Fig. 4), were produced for penetration and impact tests. After these tests, 15 transmitters were produced for deployment in free-ranging whales.

RESULTS

1. ASSESSMENT OF TISSUE DAMAGE AND SHEARING AT THE MUSCLE/BLUBBER INTERFACE

Some variability was noted in the experiments to assess mobility of the blubber over muscle in the common dolphin experiments. However, in general, net shear is greater for ventral flexing than dorsal flexing; for the lower row (lateral position of the measuring stations) than for the upper (dorsal); for deeper muscle penetration of the needle (4 cm) versus shallower (2 cm); and for stations located further towards the peduncle. Needles at the more caudal sites were also observed to bend at the blubber muscle interface with flexion. With the oscillator, there was no obvious gross trauma evident in the muscle around the tag tips. We are unclear if this is a feature of scaling, or post mortem muscular flaccidity, or a combination of both. A minority of tag flaps were disconnected at the hinge in the caudal stations suggesting greater shearing at those locations.

2. TAG DESIGN TESTING AND MODIFICATIONS

Miniature versions of the transdermal satellite tags were produced in order to match the length of and allow comparison of Mold 303B with existing dart designs used in transdermal attachments (e.g. Andrews et al. 2008, Baumgartner et al., 2015). Six different anchor designs (Fig. 3) were attached to a load cell and inserted in the carcass of a minke whale (*Balaenoptera acutorostrata*) to assess penetration and retention power. Results indicated that a tip similar to that used in the darts of the LIMPET tags would provide a more efficient penetration. They also suggested the potential for breakage of the retention blades upon removal of the tag. These results led to the development of Mold

303E, a tag of similar dimensions of Mold 303B, but with a symmetrical and sharper tip, no retention blades, and with three rows of petals with rounded and blunt edges, which were shorter and stiffer than the single petal row presented in Mold 303B. Prototypes of this new tag design were produced and underwent the following tests:

- (1) Firing in rubber belts to assess penetration power in comparison with the tip design of Mold 303B (Fig. 5).
- (2) Firing in rubber belts at elevated pressures to assess robustness of the new tip design and petal rows (Fig. 6).
- (3) Implementation of pull-out tests to assess potential for breakage and forces required to remove the tag from rubber belts and humpback whale tissue (Fig. 7).
- (4) Firing at selected targets to evaluate ballistics of the tag and the tag carrier.

Once the tests above were completed and the tag was deemed robust for deployment, 15 units of Mold 303E were produced for attachment in humpback whales in the Gulf of Maine, a population that has been subject to an intense follow-up study to assess the effects of implantable tags on their behavior, physiology, and life history (Robbins et al., 2013). These tags were deployed in July and August 2015 along with 6 units of Mold 303B for comparison. Similar versions of the latter (n=8) had already been deployed in Gulf of Maine humpback whales in 2013 and will provide additional sample to evaluate potential improvements of Mold 303E over its predecessors.

At the time this report was finalized (20 October 2015), four of the 15 mold 303E tags were still transmitting, but all units of Mold 303B had already been shed. Average duration of tags that attained greater than 75% implantation were 50 days (range = 20-90 days) and 42 days (range = 10-72 days) for molds 303E and 303B, respectively. Preliminary results indicate that tag duration may be influenced by deployment location on the body in humpback whales. Tags deployed on the hump, near the dorsal, fin have average durations of 64 (Mold 303E) and 55 (Mold 303B) days, while those deployed lower on the body have averages of 31 (Mold 303E) and 34 (Mold 303B) days. Because tags of Mold 303E are still transmitting, these results cannot be considered final. However, they already show the potential for this new design to achieve superior performance than Mold 303B.

IMPACT/APPLICATIONS

Satellite tagging is increasingly being used worldwide to study large cetacean movements, habitat use patterns, vulnerability and responses to anthropogenic activities with direct applications to conservation and management. One of the great advantages of this method is tracking individuals in near real time and sampling their environment for a lower cost than most observational studies. We expect that our results will have broad-reaching impact within the scientific community by increasing the applications of satellite tagging while reducing possible impacts to tagged whales. In fact, tag modifications, including integration of the anchor/transmitter interface, made during the first year of this project (described in our FY14 report for Mold 303B) resulted in a more robust design, which had already improved implantable satellite tag duration. This version of the tag is now commercially available and has been successfully used in various projects with significant improvement in overall tag duration (e.g. Seakamala et al. 2015; Willson et al. 2015; Zerbini et al. 2015). While further testing is required to assess consistency of the deployment durations described above before Mold 303E is made

available, results presented here indicate that changes implemented this latter design may increase performance of implantable tags even further than what had already been achieved with Mold 303B.

Evaluating possible welfare issues is important to better understand the potential impacts this technology can cause to individual animals and can inform development of improved tags. Making implantable satellite tags as effective and benign as possible will increase the number of individuals, populations, and species to which they can be applied. The tags developed under this project to date still penetrate the blubber/muscle interface and their potential impact to individual animals still requires further consideration. Therefore as part of the work originally proposed for this project, we plan to investigate blubber-only attachments using novel methods, including the use of biocompatible materials.

RELATED PROJECTS

This study has been integrated with ongoing assessments of physical/physiological tag effects and tag robustness in Gulf of Maine humpback whales (Project Evaluating Potential Effects Of Satellite Tagging In Large Whales: A Case Study With Gulf Of Maine Humpback Whales) funded by NOAA and Exxon through the National Fish and Wildlife Foundation/National Oceanographic Partnership Program). In this study, led by PCCS, implantable satellite tags have been deployed to known individuals to assess their short-term behavioral responses to tagging and potential physiological effects of tags to individual animals. Tags produced with the present ONR project have been deployed in GOM humpback whales and an assessment of the performance of new designs in comparison with the existing technology from the point of view of animal welfare as well as tag duration is ongoing.

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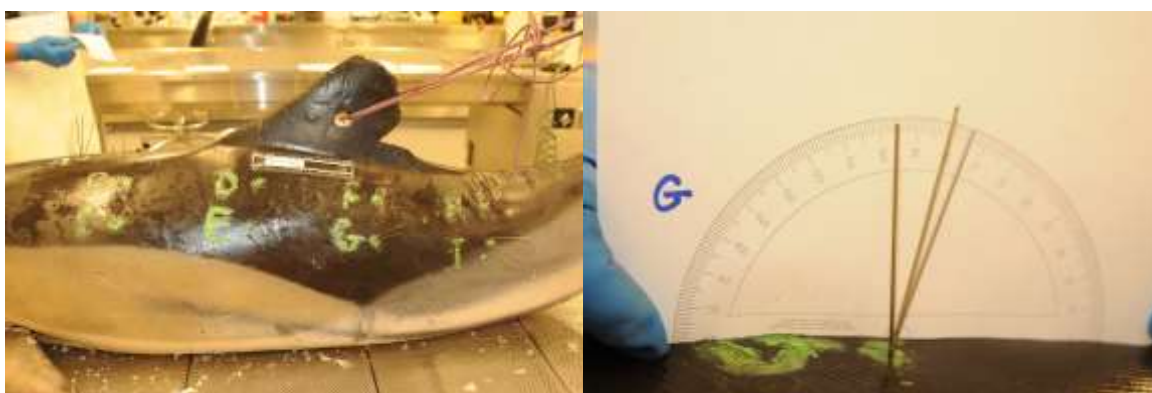


Fig. 1 – Experiment to assess mobility of the blubber over muscle in a common dolphins. Needles are inserted in nine stations along the dorsal and lateral surfaces of a dolphin (left) and the angle difference is measured (right) with the carcass in a relaxed position and flexed both dorsally and ventrally.

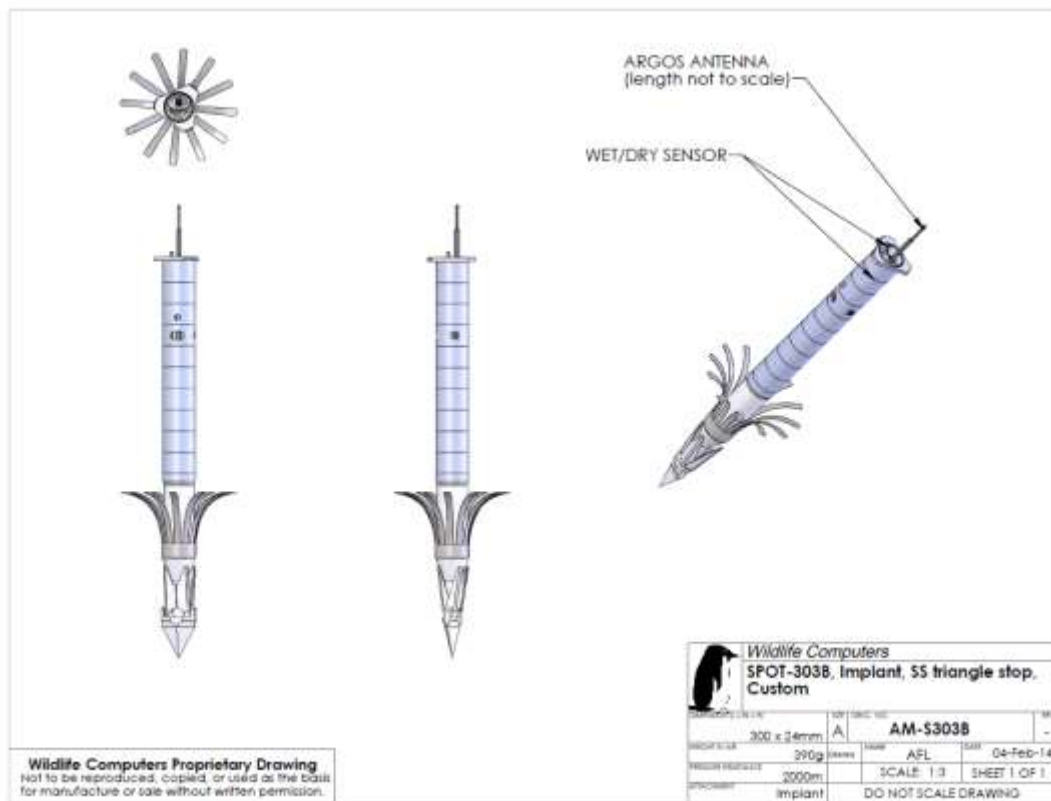


Fig. 2 – Drawing of the implantable satellite tag Mold 303C

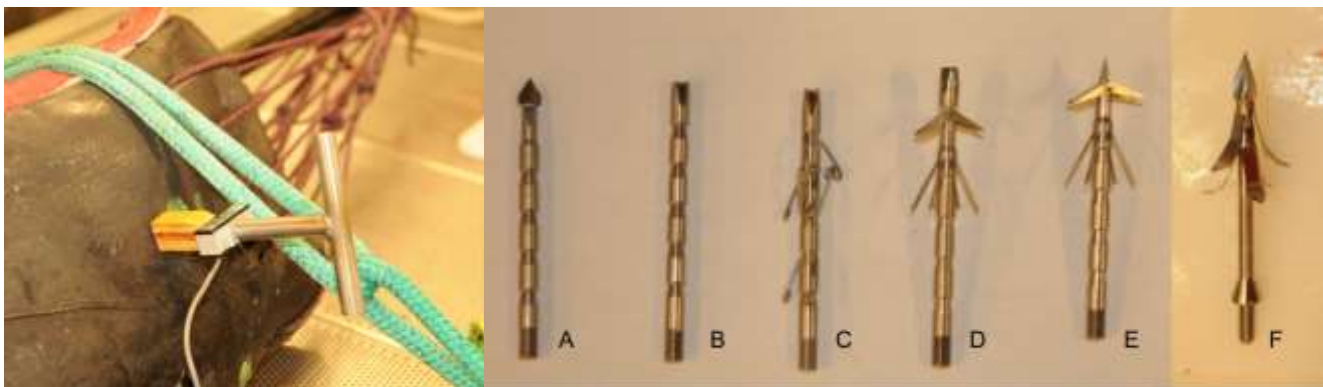


Fig. 3 – Experiment using a load cell (left) to insert and remove different types of miniature tags (right) to assess tip penetration and holding power of retention devices.

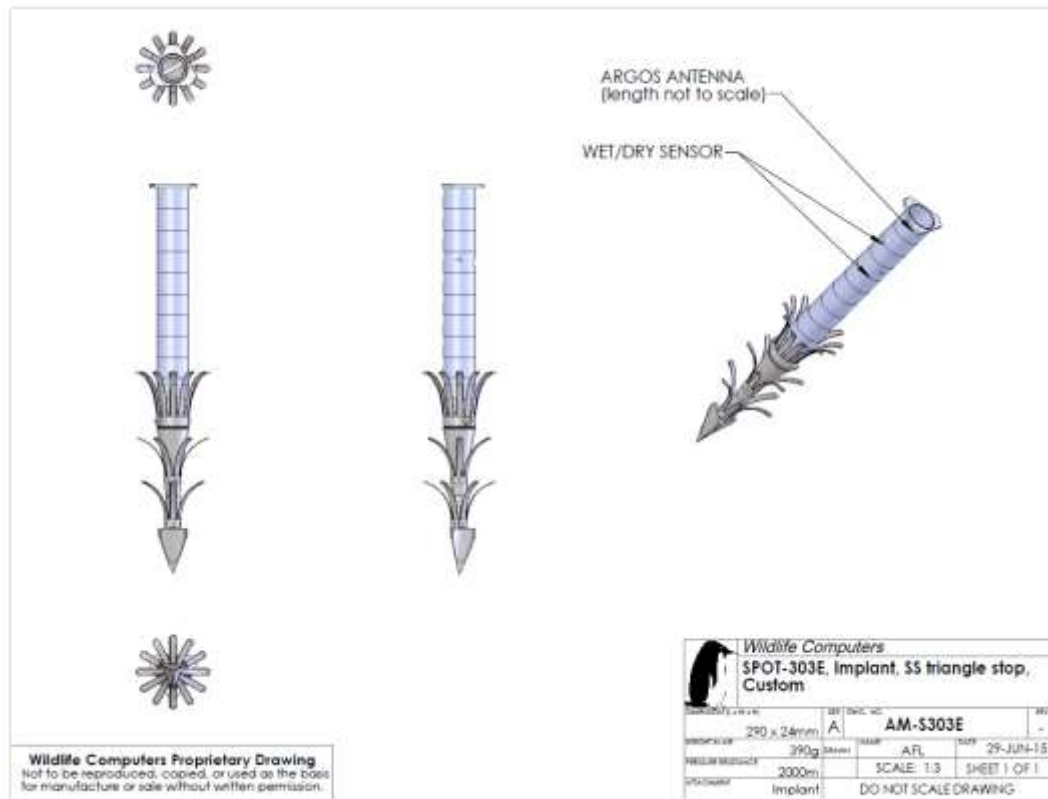


Fig. 4 – Prototype drawing of the implantable satellite tag Mold 303E



Fig. 5 – Testing penetration characteristics of tag Molds 303B and 303E in rubber belts.



Fig. 6 – Firing of Mold 303E prototype at elevated pressures to assess robustness of the housing, tip, and petal rows.



Fig. 7 – Laboratory experiment (pull-out test) to assess strength and robustness of retention petals.